2006-1114: USING JUST-IN-TIME TEACHING IN DYNAMICS AND IN MECHANICS OF MATERIALS

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Using Just-In-Time Teaching in Dynamics and Mechanics of Materials

Abstract

Over the last 8 years, the physics educational community has developed a new learning strategy known as Just-in-Time Teaching (JiTT). In this approach, students are required to answer short questions posted on the web at least two hours before class. Questions are typically open-ended and conceptual, rather than mathematical. The instructor then reads through the student answers before class and tailors the classroom experience based on student understanding. For new topics, many students will appreciate some aspects of the idea, but different students will grasp different aspects of the subject matter. By presenting the answers from the students in class, the instructor can build up an understanding of the complex idea. In this way, students feel greater ownership of the course, come better prepared to class, and have more productive interactions with the professor. This year, we utilized the technique in two mechanics courses, dynamics and mechanics of materials. Student perceptions of the technique were mixed, depending on the type of implementation and the current workload in the course. Examples of the use of JiTT in these courses are presented and a framework for applying the techniques to mechanics is described. The instructors were pleased with how JiTT provoked student thought, and the authors provide some insight into their own workload requirements when using JiTT.

Introduction

Instructors constantly seek new ways to engage their students, make them consider real world applications of engineering, and gain conceptual understanding of engineering. Just-in-Time Teaching (JiTT) can be used to facilitate these goals, and increase the quality of classroom discussion. First, we will provide an introduction to the basic components of JiTT and its underlying educational theories. Some examples of mechanics modules that were used in class, representative answers, and how the instructor modified the lesson as a result of the student input are also described. Results from a brief survey will then be presented, and discussed with instructor perceptions of the technique. Finally, references and advice on how to utilize JiTT will be supplied to potential users.

The Just in Time Teaching Approach

JiTT should not be confused with other uses of "Just-in-Time" that is prevalent in engineering literature. Other authors use JIT to represent presenting material just before it will be used, for example in a laboratory exercise or an assigned project. JiTT on the other hand, is a technique used to enhance the interactivity of a lecture period by creating a feedback loop between the instructor and the student.

As discussed in last year's proceedings[1], the JiTT strategy reflects recent efforts in cognitive psychology, developmental psychology, social psychology, anthropology, neuroscience, and education research to better understand how people learn. A recent report by Bransford[2] discusses what principles of knowledge organization underlie people's problem solving capabilities, how people transfer learning in one setting to another, and how these results can be used to design new and better learning environments. His team recommends three facets of a successful learning environment: center on the learner, center on assessment, and center on knowledge.

WarmUp Exercises

WarmUp (also called "Preflights" at this institution) exercises are the heart of JiTT. Before the class period, students are required to complete short web-based exercises from their assigned reading. These questions should be closely linked to what the instructor hopes to accomplish in class, and are usually conceptual in nature. Many instructors use the following format for their questions (although this is by no means mandatory): one multiple choice question, one essay format, and one estimation problem. The best questions ask the student to analyze a real world example, which will help develop critical thinking skills. The key is that students' answers to these problems are then used to shape the lecture.

The students should complete web assignments prior to two hours before class to provide the instructor enough time to review their answers. From the student responses, the instructor can determine if certain material needs to be covered more in depth, if main issues can be skipped, or if supplemental reading material or tutorials need to be provided. The class time can be modified "just-in-time" to reflect student understanding and interest. Seasoned JiTT instructors use actual student answers to help build their lecture or explain a theory; they will typically use overhead transparencies or PowerPoint slides of selected student responses. The class participants recognize their own words and feel ownership of the course. This can also help provide confidence to students who do not normally feel comfortable interacting during class time. Even incorrect answers, if covered tactfully, can provide tremendous insight to a difficult concept. JiTT is intended to create a feedback loop that drives the interactive classroom experience, enhancing the students' critical thinking, problem solving ability, and conceptual understanding.

JiTT Examples

Two example WarmUps are shown below, one for Dynamics (see Figure 1) and one for Mechanics of Materials (see Figure 2). Some sample student responses are provided for each example, followed by a discussion on how the instructor might interweave these answers into the lesson.

Dynamics. In the first question, students are asked to answer a conceptual question. This type of question can be used to encourage students to read the text, to require them to think at a deeper level, or just to introduce the material. The second question is conceptual and requires the student to think about what can happen physically – and write a short description for their answer. The third question asks the student to think about making an estimation of how a real world system behaves. Often they will have to find information on a website or actually take measurements to obtain an answer. It usually deals with an actual calculation, but a relatively easy one. Students are expected to include their thought process as part of their answer. These responses provide invaluable feedback to the instructor.

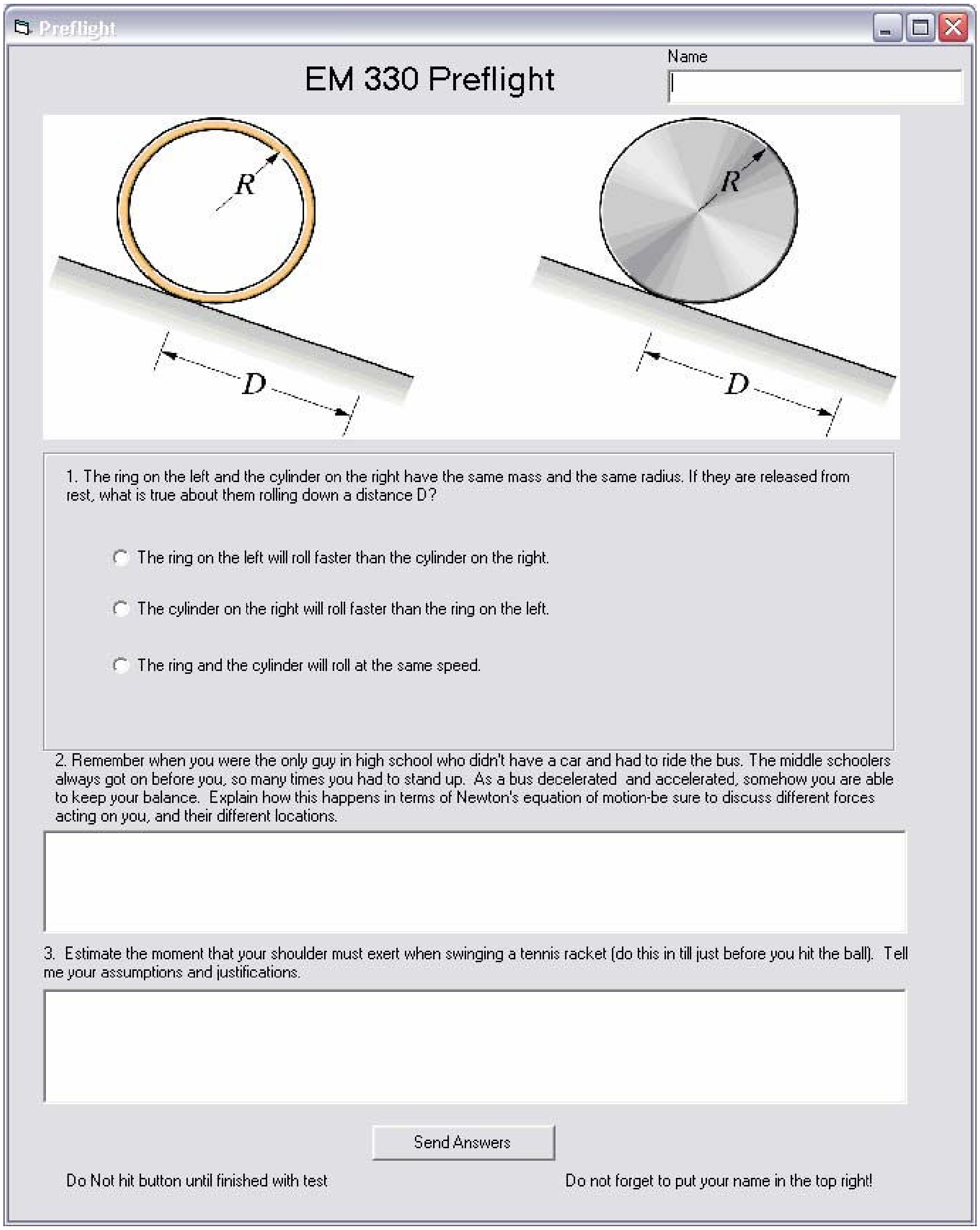

Figure 1. Example of a Dynamics WarmUp.

Some sample responses are given for the second question, which was actually borrowed from Madsen[3]:

- Standing up as the bus accelerates and decelerates, the floor exerts a frictional force against my feet, creating a moment around my center of mass.
- Well, first you have the normal force acting on the bottom of your shoes. As the bus accelerates, your weight will shift to your back foot (assuming you are standing staggered—which is more stable). As your weight shifts to your back foot you have a force exerted on your body, backwards.
- Since your center of mass is around your bellybutton it creates a moment about your feet. Thus you must lean forward so that the force of the gravity acting through your center of

mass counteracts the moment caused by the lateral acceleration. If you do it right, these two forces will equal each other and you will keep your balance.

The student responses can be used in the course to generate a great deal of discussion. Different ideas can be extracted by the professor during the lecture to help meet the lesson objectives. The friction force is certainly an important concept – but this force actually makes you want to topple backwards! The normal force must of course also be discussed. The changing normal forces could even be investigated by a physical demonstration – two bathroom scales on a moving cart could easily be brought into the classroom.

Student responses to the third question include:

- I am going to assume that I have a mass of 80 kg, and my arm has a mass of 15 kg. The center of mass for my arm is just above my elbow, in the large muscular area of my "guns". I will assume that I have a tennis racquet that I am holding in my hand that has a mass of 1 kg. Its center of mass is slightly on the "head" end of the middle of the length of the racquet. My arm is a total of .8 m long, with the center of mass about .3 m from my shoulder. The racquet will be .8 m long, with the center of mass .5 m from the end of the handle. When I hold the racquet in my hand, the total length is 1.5 m, with the center of mass at my elbow, .4m from my shoulder…. Iz=.8 kg-m2
- Here is how I would approach the problem:
    - Assumptions: Arm = 3 ft long = .91 m held at full extension.
    - Mass of racquet = 300 g (from www.head.com)
    - Cm racquet = {.35m,0,0}
    - Model racquet as a point mass at {1.25 m,0,0} (some length lost due to hand overlap)
    - Using the formula for sum of moments, we can find the moment exerted in actually swinging the racquet if we know the angular acceleration we want to be swinging at.
    - Using gravity, we can find the force exerted by the mass of the racquet.
    - 9.81 m/s2 * .3 kg = 2.94 N
    - using this as a point force acting through the center of mass, this yields a moment with respect to a shoulder of:
    - 2.94 N * 1.25 m = 3.68 Nm
- I went to http://hypertextbook.com/facts/2000/ShefiuAzeez.shtml and obtained approximately 23.13 N-m. This is based off an energy approximation. The total energy of ball at 100mph is 56.44J. This is approximately the energy the shoulder/arm must generate to propel the ball (not accounting for energy lost in follow through etc). Then, using the equation U=sum of the moments multiplied by the change in theta (estimated at 140 degrees) a moment of 23.13 is acquired.

Each of these responses can be used to build up different ideas. The first response can be used to discuss the parallel axis theorem and how mass properties of human parts are used in biomechanics. The second answer is not as correct, because the student neglected the dynamics of the problem – there is no estimate of an angular acceleration. Many students made reasonable assumptions regarding the acceleration of the arm and racquet based on the speed of a serve.

Mechanics of Materials. In the first question, students are asked a question that tests basic knowledge. This can be answered simply by the student reading the text book. It does not require in-depth thought and analysis. In the second problem, a video is shown and the student is asked to apply concepts to a real world problem. In the specific WarmUp shown (see Figure 2), the video is of an instrumented cadaver leg. The cadaver leg is forced into the ground and the cadets are asked to analyze the situation and determine how the concept of Euler buckling applies to the test. This requires the student to apply specific concepts from the reading to an unconventional situation. The purpose of this question is to promote thoughtful consideration of a specific case and how it applies to material that will be covered in class. First, students must understand the concept of end conditions and how it affects Euler buckling analysis. Second, the ideas must be applied to the cadaver leg. The student is required to make some basic assumptions about the cadaver leg, and about the test set up. The third problem continues with the real world example, but asks a more analytical question. Students are motivated to perform independent research to answer this question. Concepts found in the text book are helpful for answering the question but do not provide all the information the student needs to provide a complete answer.

Some sample responses for the second question are provided below, followed by a discussion of how these responses were used in class.

- I would use .7, the value given for one fixed end and one pinned end. The friction between the foot and the ground effectively acts like a pin.
- I would pick K=1 since both the knee and the ankle would act like pins.
- I would use a K value of 2 because there is one fixed end and one free end.
- It was hard to tell what exactly was happening in the film, but it looked like the leg was being pushed on from the top and was being smashed into the ground. If this was what was happening, I would probably use K=0.5 to represent having 2 fixed ends.
- 1, because the leg's support simulates 2 pins, one at the ground and the other at the pelvis.
- The K value would be 2, because it is most like a fixed and free end.
- We would use a K=1 because both ends are would be pinned (knee joint and ankle joint).
- It would be K=0.5 because the ends would be fixed.
- Both ends would essentially be fixed. The foot would be fixed against the ground due to the forces being applied to it, and the knee would be fixed to something to apply a force. Therefore the K value would be .5.
- I would say K=1. The knee and ankle have a considerable amount of movement, and would probably act like pins.
- K=.07 because one end is pinned at the knee and the other end would be fixed on the ground

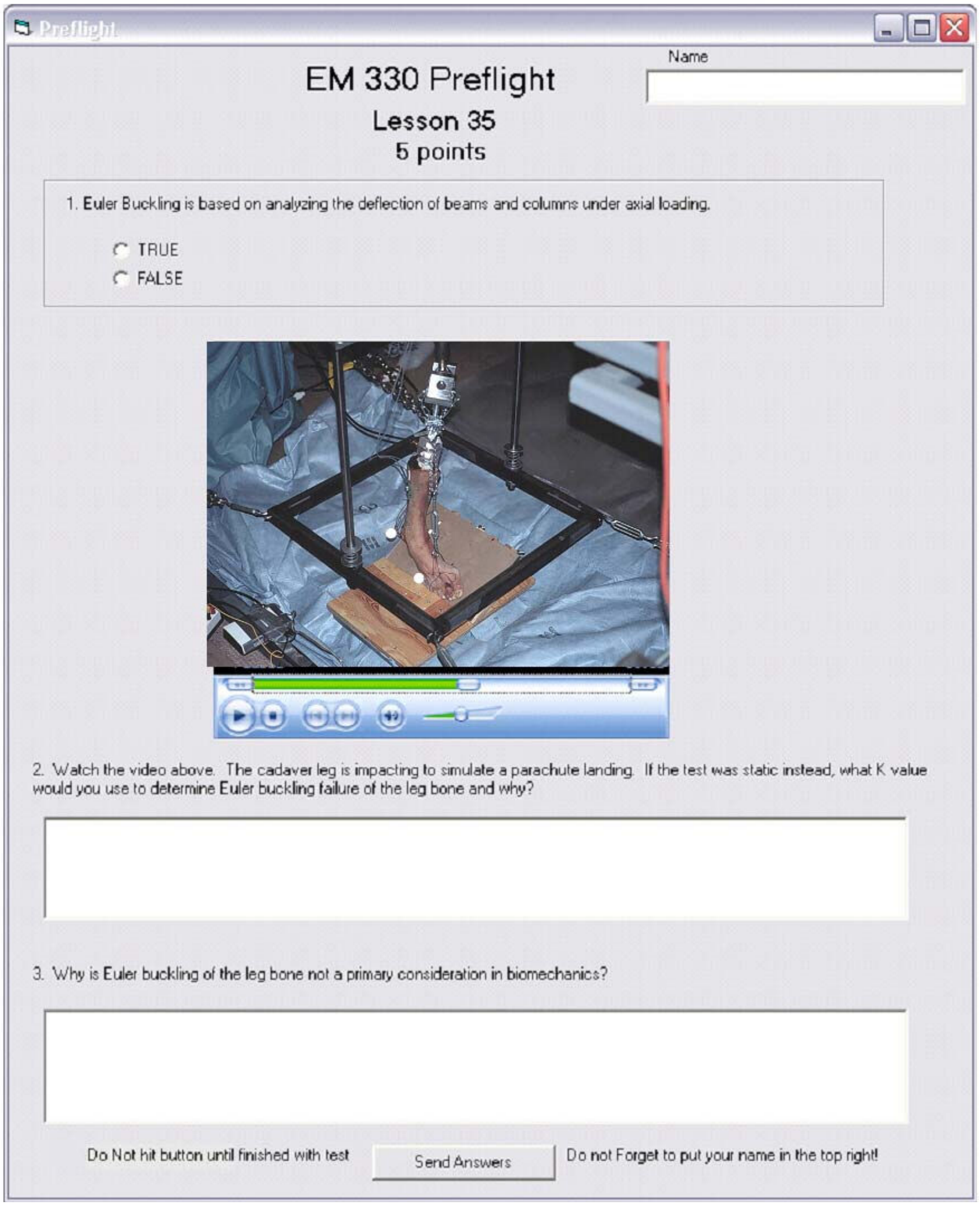

Figure 2. Example of a Mechanics of Materials WarmUp.

In the context of the lesson material and depending on the student's reasoning, there is no wrong answer. The primary purpose of asking an open ended question like this is to generate thoughtful discussion. The instructor presents a few representative responses and points out why a certain response is correct or incorrect. In Euler buckling analysis, the value of the constant K depends on the end conditions of a loaded column. This is known as the *effective length factor*. In this question, students are required to estimate the effective length factor based on assumptions they make about the end conditions of the cadaver leg test setup. Using practical experience they have of their own joints, students estimate the K value of the test setup. The answers vary from modeling the ankle and knee as pins, to modeling both ends as fixed based on how the students understood the test setup. This easily leads to a discussion of how end conditions affect the buckling load and how such loading affects the human body from a structural perspective. Even the last response of K=.07, which is incorrect based on the student's justification (it should be K=.7) can be used to launch into a discussion of what the K factor means and how lower values affect the solution. Students can discuss the significance of K=.07 versus K=.7.

Let's explore how to use the student responses to the third question, shown below:

- Because the top of the leg is not fixed to a machine that rams it straight into the ground as it is in this case. In real life, a person would probably roll their leg before it broke.
- Because bones are rather brittle. Also, the muscle mass around the bones has an effect on how the bone might bend or break.
- I don't think it would be a primary consideration because in a leg, there are other factors that take part in stabilizing the leg, like ligaments and tendons; it's not just the bone.
- Bones typically don't buckle, they just break.
- Typically biomechanics only considers the body within itself and its movement, whereas buckling would only come into play where large axial load is applied but typically muscle failure is the first to go, and bend the joint.
- Because in the body failure tends to occur at the joints rather than in the bones themselves
- Because the leg bone has joints that can relieve the impact when landing.
- Because a human leg does not nearly enough resemble an ideal column. It is not perfectly straight, not completely homogenous material and has connections other than pins, The load is also not always applied through the centroid of the cross section.
- It is unrealistic because you don't just have bone, you have muscle tissue as well. Also, the body often reacts to injuries or anticipated injures keeping you from hurting yourself that badly.
- Because bones are more like posts, they never really bend, they just fracture or yield. Euler buckling is concerned mainly with bending, not fracturing like bones do.

Students applied the basic assumptions of Euler buckling and explained how the given example violates those assumptions. A good lead question is the statement made by one student that "Bones typically don't buckle, they just break." This would raise questions in class such as "Why don't legs buckle elastically" and "Why do bones typically break rather than buckle." Such questions would result in a discussion on what Euler buckling is based on, the composition of bones, and how this changes the assumptions Euler buckling is based on.

The overall result of this Preflight is that students:

1. Came to class after having done the reading.
2. Came to class after having put some thought into what the concept presented in class is about and how it relates to the real world.
3. Came to class with a basic *working* knowledge of the concept to be covered in class.
4. Began class exploring the various aspects of a concept, such as its proper application and its shortfalls.

JiTT Implementation

Implementing and using JiTT in class does not reduce workload on the instructor. However, it makes the time spent with students more effective and more enjoyable. There is more two-way communication between student and teacher and better student-teacher interaction. Students are not asking mere knowledge-level questions such as definition of terms. Instead, students come to class having put effort into understanding the course material on their own, and with questions about application rather than basic knowledge. Because of this instructors, as well as students, find class time more enjoyable.

However, it takes more time to prepare for class. JiTT questions take more thought on the part of the instructor, as well as the students. The instructor must not only determine what information to present in class, but also consider the level and capability of the students. Student answers must be analyzed and the instructor must determine both content and method of the JiTT portion based on student responses. This takes much more time than usual lesson preparation. For example, VisualBasic can be used to create an application through which students submit their responses to the Preflight questions, and the responses are recorded in a text file. For an instructor familiar with VisualBasic, creating the application usually takes about 15. However, researching and writing the questions, analyzing the responses in the text file, and then preparing the responses for discussion can take an additional hour or more for an experienced JiTT user, depending on the material.

There are a number of methods for creating and administering JiTT WarmUps/Preflights:

1. Database driven and implemented on a server.
2. Application based (e.g., using VisualBasic, described in the example above).
3. Paper based.
4. Email based.

There are various pros and cons to each method. For example, the setup required for use of a server based system which administers the Preflight and records the answers requires a large amount of work up front. Scripts must be written and loaded on the server. An application can be created using VisualBasic and the learning curve for that is less steep. But the instructor and the students both need “write” privileges to the server where the answers will be stored. A hard copy paper based system will work, but the hard copy must be provided to students before they come to the lesson that will be covered. Also, the students must either turn their answers in to the instructor with enough time for the instructor to prep for class, or the instructor must use the data in an impromptu fashion since there will be no time to use the data before meeting with the students. The final method is to have students email their answers prior to class, but this does not provide anonymity. Additionally, the instructor must then compile the student answers from each individual question instead of having it done automatically. An alternate solution is to have a trusted agent such as a department secretary or education technician gather the data from the emails and provide them to the instructor minus student names.

Assessment

We gave students a brief survey to better understand their perceptions of using Preflights for class. They were asked to rate the following statements on a Likert scale of 1 – 5:
1= strongly disagree, 2= disagree, 3= neutral, 4= agree, and 5 = strongly agree.

1. Preflights have motivated me to read the textbook before class.
2. Prelights have helped me to identify key concepts for the lesson.
3. I learned more during class time because I completed the Preflight before class.
4. The Preflights made me consider real world applications of Mechanics.
5. I like the way the professor uses the Preflights to generate discussion in the classroom.
6. The course should use more Preflights the next time it is offered.

Two disgruntled students who scored every question with a rating of 1 were deleted from the data, and the average scores for the Dynamics and the Mechanics of Materials (labeled "Str Matls") courses are shown in Figure 3.

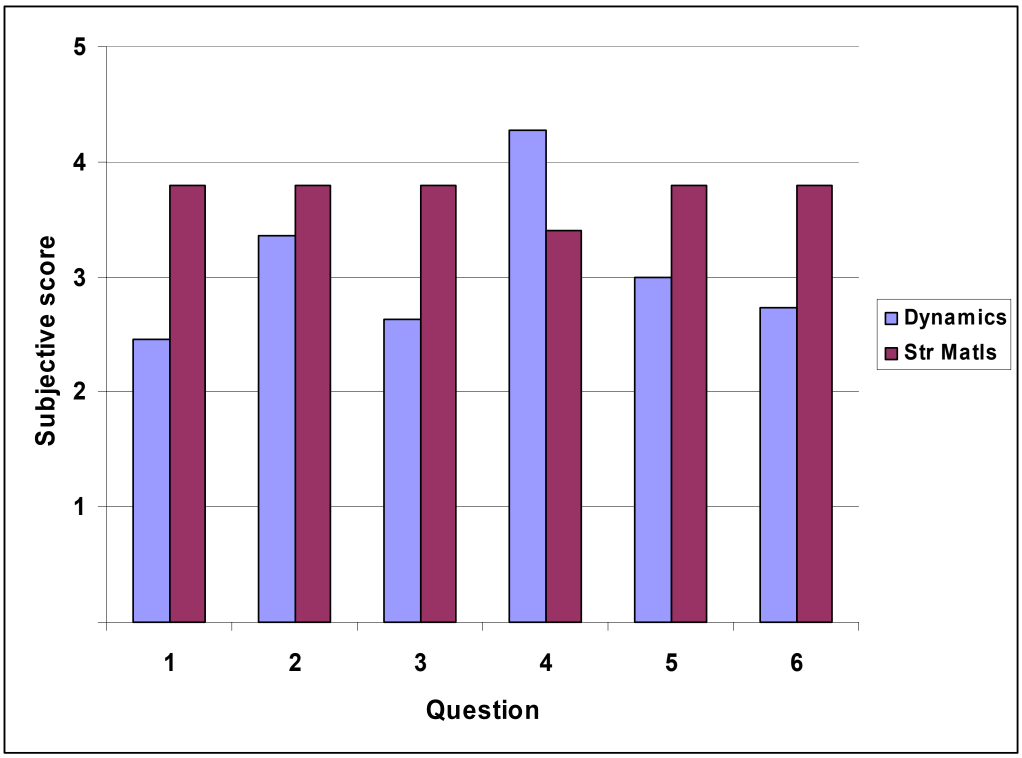

Figure 3. Survey results of students using Preflights.

The results from the survey reveal two basic patterns. The first is the different goal each instructor had when developing the Preflights. The Dynamics professor created his questions to force the students to think about real world applications. Preflights were given after a topic had been introduced, so students didn't need to delve into the text books. In the Mechanics of Materials course, the instructor's goal was to have his students come prepared to class. The second pattern reflects the overall attitude that students have towards Dynamics at this institution. It is one of the most difficult courses for engineering students, and in general they don't want to increase their workload.

There were a number of subjective comments as well.

Dynamics

- The Preflights didn't really force me to get into the book and look at concepts as much as it made me think about the things that happen in everyday life and how they are related to dynamics. When a preflight was assigned, I spent more time looking for websites that had the weight of a car, or the diameter of a tire than I did in the text book trying to figure out new concepts. Changing the nature of the questions might force students to look into the book for Preflights.
- I did not like the Preflights at all. They seemed to be too open ended.
- I would have it set up on a website so we know in advance when the preflights are due, sometimes we were sent out emails saying to do the preflight the day before and with the semester winding down it didn't leave much time to really sit down and think about the questions asked. other than that I liked how they really applied to real life applications....most of the problems in the book are springs hitting a wall or cranes swinging a weight which is useful, but not really applicable.
- I think they would have been better if started them at the beginning of the semester.
- I would have Preflights set-up for the whole semester ahead of time, so that people could do them not only the night before but in advance if they wanted to. I learned more from the pre-flights usually than i did in class when we did them.

Mechanics of Materials

- I thought they were pretty good how they were, relatively simple, short, but gave you an idea of what was going to be covered
- I like them, and the fact they were effort graded made me want to do them
- I thought the Preflights were a good idea. They got me into the material before class. I just wish they had been done all semester long instead of just at the end.
- Ask more real-world questions. I liked the Euler Buckling preflight where you asked the question about a parachutist landing. It made you consider real world applications.
- Maybe let us know a littler earlier before they are due

There are more detailed assessment studies on the effectiveness of JiTT. An excellent review of the use of JiTT at Indiana University Purdue University Indianapolis (IUPUI) was presented at the 2003 ASEE Conference[4]. The authors looked at JiTT's effect on student retention, students' subjective attitudes, and students' improved learning. First semester introductory mechanics attrition rates (which included grades below C-) improved by nearly 20%, with a rate of about half that of an introductory electricity and magnetism course. Over 85% of students answered yes to the question, "Do you feel that the WarmUp assignments and other web assignments caused you to stay caught up on class material," and 88% agreed that WarmUps are a good idea.

Another excellent article from IUPUI examined the use of JiTT in Biology[5]. Assessment results included: trained classroom observers reporting greater student-faculty interaction in JiTT classes; 87% of students rating Warm Ups responses as "very useful to learning the fine points";

retention rates improving; self-reported class preparation was higher in JiTT courses; and WarmUps resulted in less "cramming" when preparing for exams. Some of the most interesting results involved the cognitive gains shown in the course. A twenty question multiple choice test measuring conceptual understanding in Biology was given to students before and after the course. A normalized gain was computed using these results, and increases were found for the following cases: questions on concepts that were discussed in class without additional classroom activities showed a 15% gain; questions reinforced by homework problems showed a 21% gain; questions reinforced by either WarmUp questions or a cooperative learning activity showed a 52% gain; and questions reinforced by both WarmUps and cooperative learning activities showed a 60% gain.

JiTT Implementation Resources

Using the JiTT approach can be somewhat daunting for the first time user. It can be difficult to come up with appropriate questions, challenging to implement the questions on the web using HTML or other web applications, and complicated to make the classroom experience truly based on student feedback. Fortunately, the JiTT community is extremely collaborative and many resources exist to aid the new user. The first is an entire book, *Just-In-Time Teaching: Blending Active Learning with Web Technology*[6]. This reference discusses the different implementations used, theory behind the technique, and contains numerous examples.

Several different web sites also exist that are extremely useful to the JiTT user. An overview of the topic can be found at www.jitt.org. This site provides background material on JiTT, presents a number of examples from a variety of disciplines (as well as some representative answers), and lists current JiTT users from across the country. A companion website, www.jittdl.org, is also being created and it will provide a database of possible questions for JiTT users, plus a suite of other resources.

A tutorial on creating your web contact can be found at www.jittweb.org, and *Just-In-Time Teaching: Blending Active Learning with Web Technology* contains additional information on tools for implementing JiTT. It contains basics for embedding Java and JavaScript, especially for physics animations. It also provides the basics for using HTML Forms, CGI applications, and Perl scripts on web servers to implement JiTT applications and tools.

Conclusion

Just-in-Time Teaching is an innovative new teaching strategy that combines the technological advances of web-based learning with highly effective lecture techniques of interaction and engagement. While JiTT is commonly used in the physics community, there is little evidence of its use in the engineering classroom. Although the authors are unaware of any use of JiTT in the engineering mechanics community, it seems that the technique could be easily applied in this discipline. We provided the groundwork for mechanics instructors to utilize this new pedagogical approach, and listed resources to aid in the implementation of JiTT. It is hoped that the engineering mechanics community can benefit from this approach as much as the physics education community.

Acknowledgments

The authors would like to thank Mr. Don Pippin for his help in setting up the VisualBasic template that was used for all subsequent Preflights. The views expressed are those of the author and do not reflect the official policy or position of the US Air Force, Department of Defense or the US Government.

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Appendix

Other questions asked in Dynamics WarmUps/Preflights:

- You went out and bought a fancy new car that can go from zero to 60 mph pretty quickly. Using work energy relations, estimate the work required during this acceleration. Don't forget to include the rotational components of your wheels!
- The toughness of metals is important when designing structures, aircraft, automobiles, etc. It is important to know how much energy different materials can absorb during a crash or impact. How would you design a test structure to measure how much energy materials can "take?" How big would your test specimen be?
- In terms of our dynamics equations, explain how a diver can do all those amazing twists and turns.
- Dr. Davis, who has visited this class a couple of time to make sure that Dr. Self isn't messing up too badly, was the pinball wizard of his class (years and years ago). Estimate (and explain how you got those answers) the values for the variables you would need to solve for the angular momentum of the flippers.
- What type of damping do you want for your car suspension? Realizing that there are four wheels, what is the danger of making the damping too high?

Other questions asked in Mechanics of Materials WarmUps/Preflights:

- How would you use what you know about beam deflection to solve for the reactions on a statically indeterminate beam?
- Where would you expect maximum deflection to occur on a statically indeterminate beam. Tell me your assumptions and justification.
- What applications, in addition to trusses, might you use conservation of energy for determining displacement? How are displacement of the structure and deformation of the members related?
- What are the limitations to using conservation of energy for determining displacement?
- What does the partial derivative, $\delta N/\delta P$ physically represent?
- Can the Castigliano method be used if the force applied at the joint and in the direction of interest in not zero? Why or why not?